Measurement of the Optical and Radiative Properties of High-Temperature Liquid Materials by Fourier Transform Infrared Spectroscopy

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Basic to the understanding of high-temperature materials in the liquid state is first measurement of the optical and radiative properties. Unfortunately, very little spectral emissivity data are available for high-temperature liquid and solid materials in the wavelength range 2 to 20 µm. These data are virtually nonexistent when the case of undercooled materials is considered. The use of fourier transform infrared (FTIR) spectroscopy to investigate the radiative and optical properties of high-temperature liquids is proposed.

The first objective of this program is to fully develop the use of FTIR spectroscopy for the purpose of determining, at a high rate of speed, the normal and total hemispherical emissivities. Spectral emissivities would be measured in the 2- to 20-µm wavelength range for high-temperature liquid and undercooled materials. Due to the nature of the approach, the spectral emissivities can be determined quickly over the complete wavelength range. The measurements would then be conducted over a wide temperature range, including the deeply undercooled state. The second objective of this research would be to apply this technique to materials that are of current interest to the MSAD program; in particular, where there is a strong need in the numerous furnace programs and containerless programs which include electromagnetic, electrostatic and acoustic levitators as well as the 105-Meter Drop Tube Facility at MSFC. A third objective would be to provide optical and radiative property data for nucleation and solidification theories.

The overall approach is to use the FTIR spectrometer to measure the intensity of light emitted by a high-temperature liquid sample. Due to the intrinsic nature of FTIR techniques, the light intensity can be recorded over a wide range of wavelengths (2 to 20 µm) in a rapid manner, on the order of 100 spectrums per second. Spectral emissivity values for any given wavelength would be found by comparing the spectrum for a liquid sample to a spectrum recorded using the same optical path, from a standard. The standard would be a blackbody source such as a solid sphere of tungsten with a precise blackbody hole located in it. Additionally, laser polarimetric techniques which have been developed for emissivity measurements on liquids, would provide additional verification of calibration of the FTIR. Absolute specimen temperature measurements would be obtained with a aid of a singlecolor pyrometer operating at a wavelength where an independent measure of the spectral emissivity has already been determined with the aid of the laser polarimetric method. Once an FTIR spectrum is obtained, the normal spectral emissivity over the 2- to 20-µm range is derived. The spectral hemispherical emissivity (SHE) would then be derived in one of two ways.

Research in the FTIR program over the past year has been in the design and development of the FTIR system and adaptation for the specific purpose of measuring the high-temperature optical properties of undercooled metals. A complex innovative optical system has been designed and developed. In addition, a modified electromagnetic levitation system has also been designed and is nearing completion. Immediate plans are to begin measurement of the optical properties of standard samples and blackbodies to be used as calibration sources. Next the research will concentrate on the optical properties of undercooled high-purity elements, such as zirconium and niobium.

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Biographical Sketch: Dr. Michael B. Robinson came to Marshall Space Flight Center in September 1976, and currently is a member of the Crystal Growth and Solidification Physics Branch in the Space Sciences Laboratory. He currently serves as project scientist for the MSFC 105-Meter Drop Tube, for the modular electromagnetic levitator, and the German TEMPUS space flight electromagnetic levitator, scheduled to fly aboard the Space Shuttle on the International Microgravity Laboratory–2 mission. In addition, Robinson is currently co-investigator on two flight programs, one involving the study of the effect of microgravity on the nucleation distribution of pure metals, and the other involving directional solidification under microgravity conditions and influences of magnetic fields. He also serves as co-investigator on a ground-based research program involving undercooling, nucleation, and solidification studies. Robinson received his M.S. in physics from the University of Alabama in Huntsville and his Ph.D. in materials science from Vanderbilt in May 1988.